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A brief review of the present state of knowledge regarding the relationship of water hardness to cardiovascular disease. Also included are recommendations for future research and a statement on the appropriateness of modifying current water treatment practices.

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WATER HARDNESS AND CARDIOVASCULAR DISEASE

Prepared for the

Environmental Protection Agency

by the

Epidemiology Subcommittee

Safe Drinking Water Committee

Board on Toxicology and Environmental Health Hazards

Assembly of Life Sciences, National Research Council

National Academy of Sciences

Washington, D.C., 1979

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This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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WATER HARDNESS AND CARDIOVASCULAR DISEASE

The Present Status of Knowledge

The following statement regarding water "hardness" appears in Drinking Water and Health (NAS, 1977), a report of the National Academy of Sciences-National Research Council Safe Drinking Water Committee (SDWC).

> Hardness may be defined as the sum of polyvalent cations present in water. The most common such cations are calcium and magnesium. Hardness is usually expressed in terms of the equivalent of calcium carbonate ($CaCO_3$). There are no distinctly defined levels of what constitutes a hard or soft water supply. Generally water with less than 75 mg/l (ppm) of $CaCO_3$ is considered soft and above this concentration as hard.

The use of 75 mg/l as the concentration separating soft and hard water was derived from practical considerations of effects, such as boiler scaling, rather than from observations on human health. This classification of waters as hard or soft is an oversimplification of the concept of hardness since the major contributors to hardness, calcium and magnesium, vary in relative proportions. Moreover, the classification does not describe quantitatively the possible presence of a wide range of polyvalent cations, including strontium and barium, which are sometimes found as trace elements in waters. Concentrations of vanadium, lithium, chromium, and manganese are higher in hard water. Cadmium, lead, copper, and zinc tend to occur in soft water at the tap, largely as a result of the greater corrosiveness (aggressiveness) of soft water in the distribution system. However, untreated hard water sometimes contains high levels of these elements. Therefore, the pattern is variable.

The chemical composition of water that is softened by municipal treatment or in the home will depend upon the softening method that is used. Ion-exchange methods raise the concentration of sodium in water, an effect that may have adverse consequences for health, at least for some individuals.

Current knowledge is derived largely from "ecological" epidemiological studies, in which individual exposures or risk factors have generally not been considered. These studies were reviewed extensively by the National Academy of Sciences-National Research Council Panel on

the Geochemistry of Water in Relation to Cardiovascular Disease (NAS, in press). The status of knowledge in this field may be summarized as follows:

1. In general, when studies encompass large geographical areas, hard water is correlated with low cardiovascular disease rates. This correlation breaks down when smaller areas are considered or when the studied populations are grouped by altitude or the proximity of a seacoast. Some noncardiovascular ailments are also associated occasionally with soft water areas, raising the possibility that soft water may merely be a concomitant of some more basic risk factor.

2. Most studies have reported correlation coefficients and not risk estimates as a function of exposure. A few of them contain sufficient data for risk estimation: upper estimates of risk ratios for soft compared to hard water average at approximately 1.25 for cardiovascular disease and 1.2 for arteriosclerotic, stroke, and hypertensive diseases (NAS, in press).

3. From autopsy studies in Canada and the United Kingdom, investigators have reported low magnesium levels in various tissues (heart, diaphragm, and pectoral muscle) of persons who died from myocardial infarction compared to those who died from accidental causes. They observed similar deficits in persons from soft water areas as compared to hard water areas. However, conflicting data have been reported.

The SDWC is aware of detailed studies that are in progress in Canada and in the United Kingdom. The results of these studies should begin to become available in early 1979.

Recommendations for Alteration of Current Practices

Given the current status of knowledge regarding water hardness and the incidence of cardiovascular disease, it is not appropriate at this time to recommend a national policy to modify the hardness or softness of public water supplies. The data do not indicate clearly which (if any) additions to soft water would benefit human health. However, certain factors need to be considered carefully before individual decisions can be made.

Municipal authorities who are either softening their water supplies or are considering it should carefully assess the necessity for this treatment. If they decide that it is essential, they should select a method, such as lime softening, that does not elevate sodium levels.

Ion-exchange resins are often used to soften water, particularly in home water supplies. The ion-exchange process softens water by replacing calcium or magnesium with sodium. One atom of divalent calcium or magnesium is replaced by two atoms of sodium. In terms of actual weights of the elements, 100 mg of calcium would be replaced by about 115 mg of sodium. Thus, softening can result in increases in the concentration of sodium in the softened water. Avoiding such an increase might be prudent given the state of knowledge on effects of sodium consumption. The increase in the sodium concentrations in the water caused by ion-exchange softening is a direct function of the hardness level of the untreated water and the operating efficiency of the softening device. When a physician advises that an increase in sodium intake is undesirable, a "three-line system" should be used if soft water is desired for laundering and bathing. The line that supplies the drinking water taps bypasses the softener thus preventing the consumption of water with an increased sodium level.

Recommendations for Future Research Priorities

Further studies should be conducted on the relationship between water hardness and cardiovascular disease. Repetition of the types of studies that have generally been conducted to date is unlikely to yield the information that is necessary for the determination of a nationality applicable policy.

Epidemiological evidence should be gathered from studies of individual exposures to different water supplies, from studies of communities that have experienced changes in their water supplies, such as those resulting from discontinuation of softening, and from composition of their drinking water. Studies to assess mortality rates should be controlled for such intercommunity differences as ethnicity and smoking. Some of these opportunities for studies could, with relatively little expenditure, be turned into very useful controlled prospective epidemiological studies if sufficient time is available for careful planning of control populations and maintenance of migration records.

The results of clinical research from two types of studies may provide useful information on the relationship of water hardness and cardiovascular disease. Tissue samples obtained during autopsy should be analyzed for a variety of elements, including magnesium, sodium, silicon, lead, and copper, and results examined for association with

specific causes of death. Controlled trials of magnesium supplements (as fortified food or tablets) with groups of individuals at high risk of cardiovascular disease could also provide useful information.

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